Station temperature data have been collected and processed by the National Meteorological Information Center (NMIC) of the China Meteorological Administration (CMA). Monthly mean (maximum and minimum) temperature data for mainland China from January 1900 to December 2006 are used in this paper. They were introduced in Li et al. (2010); the earlier part (1900–50) of the dataset included the homogenized data series for all the stations collected, and the later part (1951–2006) is based on the China Homogenized Historic Temperature dataset (CHHT1.0), which have been strictly quality controlled and homogenized (Li et al. 2004, 2009). The later part of the dataset (1951–2015) was updated in 2013 as follows (Xu et al. 2013).

The 825 National Reference or Basic Stations (NRBSs) are shown in Fig. ES1. According to the China Meteorological Industry Standards (China Meteorological Administration 2006), any change at a national meteorological station shall be documented in a standard form (China Meteorological Administration 2005). These station history data files (i.e., metadata) are checked and stored by the provisional meteorological information centers (PMICs) and also by NMIC. Table ES1 reports the statistics of station relocations.

The observed values were quality controlled using the NMIC conventional procedures, including the climatological limit check, the station or regional extremes check, the internal consistency check, and

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Never</th>
<th>Once</th>
<th>Twice</th>
<th>3 times or more</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of stations relocated</td>
<td>156 (18.9%)</td>
<td>231 (28.0%)</td>
<td>203 (24.6%)</td>
<td>235 (28.5%)</td>
<td>825 (100%)</td>
</tr>
</tbody>
</table>
temporal and spatial consistency checks (Li et al. 2006). We then homogenized the time series of daily maximum and minimum temperatures recorded at 825 stations across China, separately, over the period from 1951 to 2010, using both metadata and the penalized maximum t test with the first-order autocorrelation being accounted for to detect changepoints, and using the quantile-matching algorithm to adjust data time series to significantly reduce the impacts of discontinuities (Wang and Feng 2010). Station relocation was found to be the main cause for discontinuities, followed by station automation. The effects of discontinuities on the estimation of long-term trends in the annual mean and extreme indices of temperature are illustrated, and the data homogenization is shown to have improved the spatial consistency of estimated trends (Xu et al. 2013).

Another observational dataset used in this paper is CRUTEM4 (Jones et al. 2012), which represents global historical near-surface air temperature anomalies over land, and the National Oceanic and Atmospheric Administration’s (NOAA) Global Historical Climatology Network (GHCN; Lawrimore et al. 2011) is also used to estimate trends. It is noted that the series from CRUTEM4 and Li (Li et al. 2010) and Wang (Wang et al. 2014) are highly consistent in their
decadal-scale variations. CRUTEM3 (for China), which represents global historical land surface air temperatures, and Li have different station densities and processing routines, but they have the following similarities: 1) the monthly average SAT is the arithmetic average of the monthly average maximum and minimum temperatures (in some other datasets in China, daily average values are calculated from the average of observations at fixed times [0200, 0800, 1400, and 2000 Beijing time (BT)]); 2) systematic homogeneity tests and adjustments are carried out over the series of historical observations at the stations; and 3) the series of Li and CRUTEM4 (also CRUTEM3) are obtained based on the same statistical approach (Jones et al. 2012; Jones and Hulme 1996).

**Eastern and Western China SAT Series.** More discussions have focused on building an SAT series for eastern China (Cao et al. 2013; Chen et al. 2004; Qin et al. 2005, 63–103) because there are too few stations across western China to build series for that region. The method of building the observed surface air temperature series for the whole of China has been introduced in Li et al. (2010). In this paper, the same method is used to build the series for eastern (E China, east to 105°E) and western China (W China, west to 105°E). (Figure ES1 gives the E China and W China series and the corresponding station numbers for eastern and western China.) From Fig. ES1, the W China series has similar interannual and decadal changes when compared with E China except for in the length of the series. This proves that the China SAT series (Li) can present the SAT change for the whole of China to a certain extent even if the series were built based on only the stations from eastern China during earlier years (1900s to 1920s).

**Uncertainty Assessment for China SAT Series for 1900–50.** Figure ES2 shows that for the 95% uncertainty range from sampling errors, data coverage, and all errors from 1900 to 1950 in Li et al. (2010), the average annual uncertainty is about 0.327°C during the 1940s (1941–50); thus, the decadal uncertainty would be $\frac{0.327}{\sqrt{10}} = 0.1°C$, which is smaller than 0.15°C in the 1930s and about 0.20°–0.22°C in the 1900s, 1910s, and 1920s. Most of the uncertainty comes from the limited data coverage (Li et al. 2010, see their Fig. 5), and it agrees well with
the station number changes during the 1900s to 1940s for eastern and western China, respectively (Fig. ES1).

**CMIP5 MODEL SIMULATION DATA.** The World Climate Research Programme (WCRP) has organized several phases of the Coupled Model Intercomparison Project (CMIP), focusing on model intercomparisons within a unified framework (Meehl et al. 2007; Taylor et al. 2012). Model–data intercomparison has been an important component of CMIP. With improvements in climate models and climate reanalysis techniques, the results of the model simulations have been compared at global and regional scales. In the third phase of CMIP (CMIP3), several models successfully simulated the average climate or even extreme climate changes in East Asia and China (Zhou and Yu 2006; Sun and Ding 2008; Zhao and Luo 1998; Jiang et al. 2012). CMIP5 was implemented in 2008 to provide data support for the Intergovernmental Panel on Climate Change’s (IPCC) Fifth Assessment Report (AR5; Taylor et al. 2012; Flato et al. 2013). Improvements in external forcing data, model resolution, and physical process have been made for the CMIP5 experiments and models (Wang et al. 2013). In our analysis, the results of 41 models are used [see Table 9.1 in Flato et al. (2013)].

**SURFACE AIR TEMPERATURE (SAT) TRENDS FROM 20CR.** Version 2 of NOAA/Cooperative Institute for Research in Environmental Sciences (CIRES) Twentieth-Century Reanalysis (20CR V2) dataset provides a means for quantifying uncertainty, which can be used to verify the simulations by climate models during different time periods within the twentieth century. The 20CR dataset is a preliminary estimation of variations in the global atmosphere over the time span of 1871–2010. The time resolution is 6 h, and the T62L28 reanalysis version is adopted. By using the ensemble Kalman filter assimilation technique, the first background field is provided by a global numerical prediction model. Monthly sea surface temperature and sea ice data are used as the lower boundary conditions together with estimates of past changes in atmospheric greenhouse gases and natural external forcing factors (see Compo et al. 2011). Only surface pressure data are assimilated, excluding other information such as temperatures measured at surface stations and satellite data (Compo et al. 2011). The 20CR dataset can be considered as being totally independent of measurements of temperature made at stations across the land surface of the earth. A detailed assessment of the overall quality has been reported (Compo et al. 2011, 2013), and the dataset has been used in a wide range of climate and weather applications (http://reanalyses.org), including examining the U.S. (Vose et al. 2012) and global (Parker 2011) SAT trends since 1979.
We plotted surface air temperature trends from 20CR (Compo et al. 2011), which is driven by surface pressure data. For 1998–2012, 20CR reproduced cooling over China in winter (Fig. ES3), in agreement with observations, with little change in summer (Fig. ES4). As 20CR does not use air temperature data or aerosol forcings, the winter cooling must have come from the atmospheric circulation (i.e., an increase in winds from the north responding to the assimilated surface pressure data). But 20CR provides output only on a 6-hourly basis, not true maximum and minimum temperatures, so we only looked at monthly and annual mean temperatures.

It is noteworthy that the SAT change trends derived from 20CR are similar to those from observational SAT data. This means the SAT change in June–August (JJA) and December–February (DJF) are related to regional atmospheric circulations.

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REFERENCES


